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Prepared for Delivery

at the

Armed Forces Communications and Electronics Association

Luncheon

Sheraton Park Hotel

January 3, 1974

I would like to discuss briefly with you today NASA's present plans for research and development in the communications satellite field.

As you will recall, NASA announced last January that we were making a major change in our applications programs. We announced our decision "to phase out our work on the development of experimental communications satellites." This decision was based on our view at that time that "further research and development advances in this field could now be accomplished by industry on a commercial basis without Government support." We announced that we would proceed with work on our next Advanced Technology Satellite (ATS-F), which is scheduled for launch in April of this year, but we announced that the follow-on, ATS-G, would be cancelled.

As might be expected, that announcement got a mixed reaction, and resulted in some misunderstandings. Some people welcomed the idea that we had reached a point in space communications technology where private enterprise could begin to play a more important R&D role. But concern was also expressed on Capitol Hill and in a number of agencies in the executive branch, including NASA, that private enterprise could not begin to do all that NASA had been doing in the space communications R&D field.

As a result of the ensuing discussions with all interested parties, NASA's continuing role in space communications R&D has been carefully defined and explained.

Industry is demonstrating that private enterprise is already well equipped to design and build spacecraft for early commercial use -- both for Comsat and for the new networks of domestic satellites currently planned. NASA's role in this rapidly expanding field will be limited to providing launch services.

We also recognize, however, that NASA needs to make further advances in space communications technology to meet our own needs and to enable us to provide competent technical consultation and support to other government agencies.

It is clear that the technical and management capabilities in satellite communications that NASA has developed over the past decade must be maintained and made available as other agencies request. It is important that such capabilities continue to exist within the government. Private industry can meet short-term commercial needs. But continued NASA activity is essential to identify and meet long-term national needs.

According to present plans our activities will be organized under two main headings: one, Technical Consultation and Support Services and two, Advanced Communications Research.

We are not proposing any new flight projects at the present time. But two very important flight projects already underway will be completed. These are: the experimental communications satellite, ATS-F; and the third Canadian Cooperative Applications Satellite, CAS-C. ATS-F will be launched in April of this year, and the CAS-C will be launched in the last quarter of 1975. These two current flight projects will demonstrate the basic technology for community broadcast satellites working into small, low-cost ground stations.

The HET Experiment

I am sure you are already familiar with ATS-F and why it is a significant step forward in the use of space for communications. I would like to mention briefly three of its experiments.

One is called HET, for Health/Education Telecommunications experiment. The Principal Investigator is the Department of Health, Education, and Welfare. This experiment will be conducted in the Rocky Mountain States, Alaska, and Appalachia.

ATS-F will broadcast a wide range and variety of user-developed programming in fields such as health care, medical education and career development. Men and women counselors, teachers, paraprofessionals, and volunteers will be working in the field to make certain that the target populations receive and benefit from the messages being transmitted. The new capabilities pioneered in this demonstration will be of the utmost importance in establishing future operational satellite systems by the private sector. A key element in this experiment is the interactive nature of the communications. Television coverage will be provided to remote areas by the ATS-F satellite and voice communications to the control center will be established via NASA's ATS 1 and 3 satellites. This interactive capability will allow "real-time" feedback with respect to the program content and effectiveness.

The PLACE Experiment

The HET experiment will be carried out while the ATS-F is at 95° longitude, about the longitude of Kansas City. A second important experiment will also be carried out at this longitude. It is called PLACE, for Position Location and Communication Experiment. It will demonstrate the practicality of real time communications among central ground stations, airplanes, and ships via satellite. The same communications links will be utilized for position location of both the aircraft and the ships. The U. S. Coast Guard, the Maritime Administration of the Department of Commerce and the Federal Aviation Administration are active participants in the experiment. In addition, this experiment is international in character, with participation by Canada and the European Space Research Organization (ESRO). One of the major objectives of PLACE is to provide data from which requirements may be derived for operational systems to be established later in the decade.

The SITE Experiment

A third very significant ATS-F experiment is the NASA/India Satellite Instructional Television Experiment, called SITE. Approximately one year after launch, ATS-F will be moved eastward to a location over Lake Victoria in Central Africa. From this position it will be "visible" to the Indian sub-continent. It will then be used by the Indian Government for a period of nine months to a year to conduct the SITE.

NASA will provide the use of the 860 megahertz spacecraft transponder for SITE and appropriately position and point the ATS-F, using transportable ground control facilities in Western Europe. All other aspects of the experiment, including the ground transmitter receivers and software, are the responsibility of India. The satellite will be used four to six hours a day to broadcast television programs to about 5,000 Indian villages, 2,000 of which will have community receivers for direct reception from the satellite. The programming material is being prepared by India. It will stress improved agricultural techniques, family planning and hygiene, school instruction, and cultural integration.

Other Experiments on ATS-F

In addition to the HET, PLACE, and SITE, there are twenty other scientific and technological experiments on ATS-F associated with solar radiation damage, propagation phenomena, satellite-to-satellite communications, cloud mapping, and thermal control of spacecraft. Many of these experiments will produce design data that will be utilized for future operational systems.

It is of interest to note that NASA experimental satellite programs have attracted funding from other organizations, since users are required to pay for the planning, execution and analysis of results of their experiments as well as the cost of experimental ground equipment. In the case of ATS-F, this investment by other organizations amounts to approximately $35 million.

Joint U.S./Canadian Communications Technology Satellite

Our second ongoing flight project (in addition to ATS-F) is the joint U.S./Canadian Communications Technology Satellite, also known as the Cooperative Applications Satellite, or CAS-C.

This Cooperative Applications Satellite program was undertaken to develop the technology which will make satellite communications with small ground stations feasible in the 12 GHz frequency band. This unexploited band is of particular interest to future communications systems, since its recent allocation to satellite broadcasting and communication services did not include restrictions on power transmitted from the satellite.

Technical Consultation and Support Services

Now I will review what we are doing and plan to do in the area of Technical Consultation and Support Services.

Over the last few years we have conducted special interference and propagation studies and provided consultation services in spacecraft technology and telecommunications to support NASA programs. The unique resources and expertise which are used to provide this support within NASA are also utilized to fulfill NASA's statutory obligations to support the Federal Communications Commission and other organizations at their request. Support to non-NASA organizations is on a reimbursable basis where appropriate. The program is divided into three major areas: Orbit and Frequency Utilization, Propagation and Interference Effects, and Spacecraft Systems.

First, in Orbit and Frequency Utilization, looking ahead to the 1980s and the 1990s, we foresee a greatly increased demand for existing and new satellite services, such as meteorological observations from synchronous orbit, data collection systems with thousands of surface-based radio transmitters, and Earth resource sensing. User experiments on ATS-F such as health and education and instructional television experiments are also expected to stimulate the demand for new services.

Because both the radio frequency spectrum and geostationary orbit positions are limited resources, particularly for use at frequencies below 10 GHz, growth of space applications can be severely constrained. In order to meet just the present demands, satellite system parameters such as polarization, modulation, and frequencies must be carefully coordinated to reduce the chances of intersystem interference. Where large numbers of satellites operating in the same frequency bands require similar orbit positions, the potential for radio frequency interference is large. Add to this situation the hundreds of ground stations associated with each of the domestic systems, and the need for close coordination is readily apparent.

NASA has a strong vested interest in competing for spectrum and orbit positions for its own ongoing space missions, particularly since radio interference has been experienced by NASA space systems at an increasing rate. Fortunately, no mission failures have occurred, but the chances of this happening will increase as the numbers of satellites, sensors, and ground emitters increase.

Analysis of this radio interference was initiated last year and will be continued to determine what design changes, if any, are required for future NASA missions. We will also examine NASA's future frequency allocation, bandwidth and orbit position needs and, where necessary, find ways of sharing existing frequency allocations more efficiently and strive to open up higher frequency bands, particularly above 10 gigahertz, to alleviate radio frequency and orbital space crowding problems.

Two large obstacles to opening up additional frequency bands, particularly for spacecraft-to-ground communications, are the adverse effects of propagation phenomena and man-made noise. To provide further insight into these effects, propagation and interference measurements are planned using ATS-F and CAS-C. These measurements are planned for a broad range of frequencies applicable to space applications, space research, and communications. The experiment design, hardware procurement, and spacecraft integration phases of these experiments have been completed and measurements and analyses will begin with the launches of ATS-F in 1974 and CAS-C in 1975. The results of these measurements should help make it possible for NASA and other users of space to utilize in the late 1970s and early 1980s frequency bands not now readily usable due to lack of knowledge of propagation effects in these bands. The results of these experiments will also be used by the FCC to establish guidelines and regulations for the use of assigned frequency bands and orbits.

With respect to the third element of the program, specialized studies of spacecraft systems, we will continue to make feasibility and technology assessments and design and flight readiness reviews for the FCC in the same context as in previous years. Support efforts for others will be undertaken on a request basis and will be reimbursable where applicable. Examples of this type of support include systems and propagation studies for NOAA for disaster warning satellites and technical advice on maritime applications for the Maritime Administration and the State Department. Both of these efforts were initiated last year.

Advanced Communication Research Program

NASA's Advanced Communication Research program provides the technology base to meet NASA's needs. It also helps to maintain the technological lead in satellite communications that the U. S. now tenuously holds, through the development of concepts and technology far in advance of the current and planned state-of-the-art. In addition to providing support for our own program needs, this effort contributes to maintaining NASA as the government's center of expertise in non-defense oriented spacecraft technology and space telecommunications.

Our efforts concentrate on developing methods for better utilizing the presently available microwave frequencies, and research investigations and technology explorations to open up new bands in the spectrum, such as the infrared and visible, for space research and applications. These efforts include the development of both components and spacecraft technology to produce more efficient and reliable operation.

To meet the requirement of providing unique geographic coverage by NASA, DoD, and commercial communication satellites without interference, we are developing new techniques that will permit the design of antennas to produce prescribed, irregular beam contours like the boundaries of a time zone or states. An advanced computer program for automating these new antenna design techniques was initiated two years ago at the Jet Propulsion Laboratory. This program, with the additions we are making, is a state-of-the-art tool for producing these unique antenna beam shapes while maintaining a high immunity to interference. It represents a breakthrough in antenna design, permitting the beam contour to be utilized as given at the outset of the design procedure.

Several other techniques are being developed for better utilization of presently assigned frequency bands. One is multi-level modulation. Previous studies at the Jet Propulsion Laboratory (JPL) have indicated that, of the many combinations of amplitude, frequency, and phase modulations, an optimum choice combines four levels of amplitude with four levels of phase, thus producing a 16-level system. This represents a bandwidth conservation factor of eight over a two-level system for binary data. Our efforts are now concentrated on the design of receivers and transmitters that can be constructed economically for this purpose.

Another technique that concentrates on compressing television signals, particularly for educational transmissions, is being developed at the Ames Research Center. It essentially converts, or transforms, video signals into a form from which redundancy can be easily removed. That form, known as the Hadamard-transformed signal, is then transmitted and reconverted at the receiving station into the original form. Although a small loss in quality results, the final picture is still acceptable. For classroom quality pictures, compression ratios higher than 10 to 1 have been achieved. This means that as many as 10 different television signals could be sent through a standard television channel. In cases where only a narrow bandwidth channel is available, Hadamard transformation makes single-channel educational video feasible for remote areas.

A third technique makes use of the fact that two radio signals of the same frequency whose polarizations are orthogonal (i.e., perpendicular to each other) will not interfere with each other. Polarizing antennas to receive only one of two orthogonal polarizations will allow doubling of the number of channels in a given frequency band. Although this technique is not new and is currently planned for use on several commercial communication satellites, as well as our own NASA satellites, very little is known about how effective it is under various geometrical and atmospheric conditions.

By making use of the previously mentioned computer program for antenna design, a handbook will be developed which can be used to determine what the effects of varying antenna design and geometrical and atmospheric conditions are on maintaining the desired polarization. Some physical experimentation will also be conducted to confirm the design handbook.

To open up new regions of the spectrum for satellite communications, we plan to explore and develop technology in the near- and far-infrared (100 micron) and visible (.5 micron) wavelength regions. These regions have the potential of providing communications capacity many times that presently available. Since much work has been previously done by NASA at near-infrared and visible wavelengths, we are now concentrating on basic investigations in the far infrared. In the far infrared there is a potential for developing receivers with far less inherent noise than those at the near-infrared and visible wavelengths. There is experimental evidence that wavelengths will be found which are less attenuated by the atmosphere than those at the high microwave and millimeter wave frequencies.

In components we have concentrated on two main areas: the development of low-cost, low-noise preamplifiers for the 12 to 30 GHz region and the development of highly efficient and reliable, 10 to 100 watt transmitters in the 1 to 3 GHz region. These transmitters will combine electron beam technology with solid state technology. They will cost much less than conventional travelling wave tubes and will be more suitable for mobile communication and position location applications.

In spacecraft technology we will study a rather unusual approach, called the "pinwheel" satellite, to reduce the weight presently needed by spin-stabilized spacecraft in synchronous orbit. It will make use of the solar pressure to maintain proper spacecraft attitude, thus reducing the fuel load normally needed for this purpose. This will result in a system requiring fewer solar cells to produce a given amount of electrical power.

Communications as a Substitute for Transportation

One of the areas in which we have recently initiated study efforts, and which I believe may in the future lead to a very fruitful demonstration, is in using communications as a substitute for transportation. This has also been called "moving electrons instead of people."

The rapid development of electronic communications has permitted close coordination of widespread businesses. These communications can replace much of the need for physical travel in order for people to talk face-to-face.

One aspect of this approach involves the use of communications circuits to conduct teleconferences which replace travel to a central meeting. Within NASA several major programs made extensive use of this technique. The Apollo Program instrumented eleven teleconference rooms at NASA and contractor installations. Typically, 40 or 50 pages of documents and drawings were distributed by fast facsimile machines on the day before the teleconference. During the teleconference, these figures were projected simultaneously on screens at each participating conference room. The rooms were all interconnected by high quality audio circuits connecting voice-actuated microphones. Other NASA programs which have used teleconferences extensively include the Skylab and Viking Programs. Each dollar spent in teleconferencing appears to have saved several dollars in travel funds.

These previous programs will be analyzed to determine the teleconference techniques which appear promising for future programs. Preliminary system analyses will be made to enable trade-off comparisons of telecommunications and travel on future programs. A number of candidate programs will be analyzed to predict the effects of teleconference facilities on the management of the program. An experiment will be designed for each participating program which looks promising, and an implementation plan will be developed. Following approval of the experiment design and implementation program, the most promising programs will be equipped with teleconference equipment. Such experiments will help to determine the extent to which teleconferences can replace travel in the management of NASA programs.

Candidate programs for such experiments include the Shuttle, Viking, Pioneer, and Earth Resources Applications Programs. These plans will make use of existing NASA circuits and communications terminals where they exist; will supplement them where necessary with audio and data transmission circuits; and may provide two-way video links between selected NASA installations.

Ultimately, these video links may use experimental satellites such as the joint NASA/Canadian Cooperative Applications Satellite.

In addition to these plans to use teleconferencing to reduce the amount of inter-city travel, plans are underway to extend these techniques to small neighborhood office centers which would enable NASA employees in congested cities to work close to their homes. This could sharply reduce the commuting between suburban areas and centralized urban locations. If these experiments prove to be successful, and are copied by other government and industrial organizations, they could make a major contribution towards reducing community and urban congestion problems, while saving time and energy.

Conclusion

1974 will also be an interesting year from the space communications point of view. In addition to ATS-F, we have Mariner 10 on the way past Venus and Mercury -- our first mission to the innnermost planet of the solar system. And we are planning to launch two weather satellites to synchronous orbit for operational as well as experimental use. For the first time, we will be able to keep a constant watch on tornados and large thunderstorms and other violent but short-lived storms. We can watch them form, study their life history, and in many cases give timely warnings.

This is a new kind of use for synchronous orbit, that unique region that is now opening up to the scientific and practical uses of mankind. As I have tried to stress throughout this talk, advancing space communications technology is essential to the effective use of this new region.

This is a worthy challenge to the members of this group and your colleagues throughout government and industry. It is one of the many worthy challenges that you have to keep America prosperous and strong, and to benefit all mankind. I wish you all a successful and happy New Year.

I thank you.